A Simple Method of Image Halftoning by Adding Random Numbers

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Abstract

This paper presents a simple method of image halftoning by adding random numbers in order to decrease conspicuous patterns such as regular straight lines. I proposed two simple methods, such as a binary method adding a random number and a FS (Floyd & Steinburg) error diffusion method adding a random number. In the binary method that the converted error is added to only the adjacent pixel of the right side, many regular straight lines remain after the converted image, then the images are conspicuous.

By adding a random number the converted image is more natural to look at, but the sharpness of the image almost does not decrease, that is to say, the detail of the image stays unchanged.

In the error diffusion method, where the converted error is transferred 4 adjacent pixels, the regular straight lines decrease than those in the binary method. Moreover, the adding of a random number is less effective than that for the binary method.

I evaluated quantitatively conspicuous regular patterns and edge patterns for the converted image by a numerical value, such as the sharpness, and likeness.

In both methods when the adding random number is about 40, the conspicuous regular patterns become less. Therefore, the regular patterns are fainter than those for adding random number 0.

Key Words : binary image, error diffusion, Floyd & Steinberg filter, halftoning, sharpness

1. Introduction

We always use digital cameras, video cameras and smart phones with camera functions. It is important to transfer the generated images and videos to other persons or information apparatuses, such as printers, computers using the Internet.

At this case, it is necessary to compress the image information because of reducing the transfer time of the Internet. Especially for almost black/white (mono-chromatic) printers binary quantization methods are used because they can display only

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small black dots, not grey dots. In almost all printers, the images with 8-bit resolution (256 grey levels) are converted into 1-bit resolution, i.e. binary quantization. According to a proper slice level the pixel level of a grey image is changed to a black pixel (level 0) or a white pixel (level 255).

A lot of papers deal with image compression methods for printers. They are using an error diffusion method [(1), (2), (3)], a random dither method [(4), (5), (6)] and a systematic dither method [(7), (8)].

In an error diffusion method, when a pixel in the grey image is converted to a binary pixel, the conversion error is calculated, and this error is added to the level of the adjacent right pixels, and the next new pixel level is converted to the binary level. According to the sign of the error the addition or the subtraction occurs.

In this method the conversion is achieved from a left pixel to a right one and from an upper horizontal pixel line to a lower one.

The pseudo grey image is gained by changing the binary pixel density according to human characteristics for a sense of sight. The binary conversion is called as a half-tone process, or halftoning[(1)].

In famous error diffusion methods[(1)] there are the Floyd and Steinberg (FS for short) method and the Jarvis, Judice & Ninke (JJ&N for short) method. In the former method the conversion error is diffused to 4 adjacent pixels, and in the latter method it is diffused to 12 adjacent pixels whose distance to the target pixel is about 2 pixels.

In the paper (3) grey characters in an image are converted to binary levels by heightening the slice level in order to clarifying the character edges more clearly.

The paper (4) shows that the grey image is compressed to a binary level using dither patterns that are defined in advance in order to process with high speed.

In the paper (5) a blue noise mask with the human visual system is used in order to optimize the binary image

In the paper (6) in case of converting to more than two levels for the dither matrix method this matrix is derived so as to coincide with the result of the error diffusion.

The paper (7) states that a binary process is divided into two, one is a grey level processing that the conversion error in a mesh is the diffused adjacent mesh, and the other is a pattern level process that adopts to the grey level structure in a mesh of image.

In the paper (8) generally the authors derive a closed form expression of the performance of a class of dynamic quantizers. A grey image is compressed to a binary level using the optimal dynamic quantizers that is derived from the filter of human visual characteristics.

In these papers there are not any detail analysis of the results, and they does not evaluate quantitatively compressed images. Therefore, I propose a new simple error diffusion method, and I evaluate quantitatively the converted images by changing parameters.

In Section 2, we introduce two new methods by adding random numbers. The experimental results by the computer simulation are shown in Section 3. Finally, the paper is briefly summarized in Section 4.

2. Compression Methods

2.1 Binary Method Adding Random Number

In case of compressing the image information, the simplest method is to convert a grey image (8-bit resolution) into a binary image (1-bit resolution), that is to say, into only two levels, such as a black (0) pixel and a white (255) one according to the proper slice level (regularly 128). At the conversion a generated error that is the difference between the grey pixel level (0 to 255) and the slice level, is diffused to the next right adjacent pixel level. The error has a plus or minus sign. In case of a minus sign the subtraction is achieved, on the contrary in case of a plus sign, the addition is. The compensated pixel level by the diffused error is limited below 255, and over 0. It similarly converted to the binary level. The compensated pixel level is gained by the addition in case of the plus sign of the error, in case of the minus sign the subtraction is achieved.

We propose a simple new method where a random number is added to the conversion error in order to reduce regular, conspicuous patterns.

When a grey pixel level at a horizontal index j is supposed to $Y(j)$, and the slice level is S, the binary level is 0 if $Y(j)<S$, else 255. The next pixel level adding a random number is $S-Y(j)+(\mathrm{random}(R)-R/2)$, where R is the integer number from 0 to 255, and the function random(R) of C programing language library function generates one integer random number between 0 to $R-1$. This new level is converted similarly to the binary level. Of course, the sign of $(\mathrm{random}(R)-R/2)$ is a plus or a minus.

2.2 FS Error Diffusion Method Adding Random Number

In case of the binary method the conversion error is diffused only to the adjacent pixel of the right-hand side. But in case of the FS (Floyd & Steinberg) error diffusion method the conversion error is diffused to 4 adjacent pixels as shown in Figure 1, where the numbers on the arrows are the weight coefficients at the accumulation of the 4 diffusion errors.

Similarly to the binary method I propose a new method adding the random number at the error diffusion.

Figure 2 shows that the 4 errors are accumulated to the pixel of the horizontal index. In this figure the second index displays 4 errors, that is to say, the index 0 displays the error from the left adjacent pixel, the index 1 does that from the upper right pixel, the index 2 does that from the upper pixel, and the index 3 does that from the upper left pixel.

Similar to the binary method adding random number, in the FS error diffusion method the random number is added at the conversion.

I will show a conversion process by mathematical formulas. Supposing the conversion error at the former pixel is $E(J-1)$ at the horizontal index J-1, the next pixel conversion error Er adding a random number is,

$$Er=E(J-1)(0)+E(J+1)(1)+E(J)(2)+E(J-1)(3)+\mathrm{random}(R)-R/2, \quad (1)$$

where each E is multiplied by weight coefficients, as shown in the Figure 2.

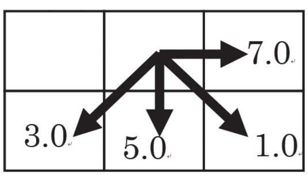


Fig. 1 In FS error diffusion method 4 errors to be diffused

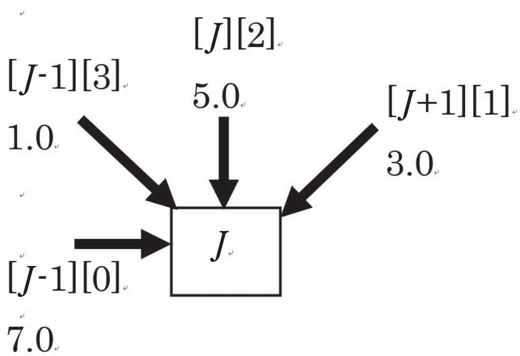


Fig. 2 In FS error diffusion method 4 errors to be accumulated

3. Experimental Results

3.1 Likeness

Figure 3 shows a tested image of the “Pepper”, that is defined by the SIDBA (Standard Image Data-Base) (9).

Figure 4 shows a compressed image by the binary method. From the figure many white straight vertical lines are seen almost in the left side, and the same patterns are repeated all over the image. We do not see it naturally.

Figure 5 shows a relationship between the likeness value and the random number in a rectangle pixel area of P1(0,130) to P2(20,150), where points indicate a left upper corner and a right lower corner for the rectangle, respectively.

Fig.3 Original color image(Pepper)

Fig. 4 Simple binary image

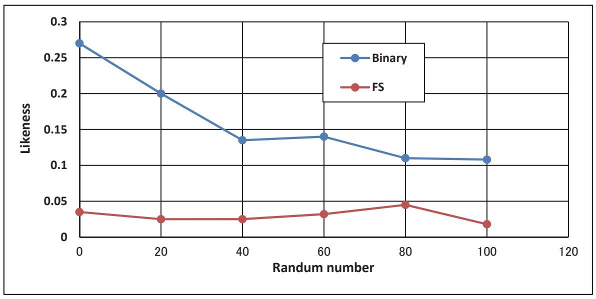


Fig. 5 The relationship between the likeness value and the random number.

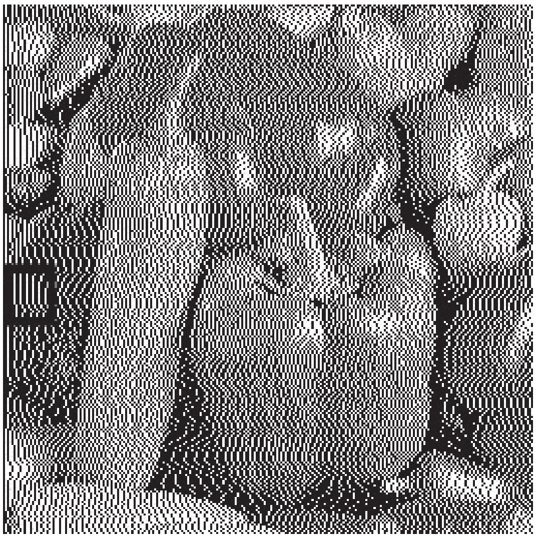


Fig. 6 Compressed image by binary method

This area is displayed as the black rectangle shape in the Figure 6. It shows the compressed image by the binary method.

The likeness of the vertical axis shows the continuous grade of white vertical lines. That is to say, the smaller these values are, the less the number of white lines are. Therefore, the images become more natural to look at.

The likeness value is defined as follows,

$$\text{Likeness} = ko/\ (M^*N), \quad (2)$$

where ko is the total pixel number where $Y(i,j)$ = white and $Y(i,j+1)$ = white. And M and N is a horizontal and vertical pixel number in the rectangle area, respectively, and the pixel $Y(i,j+1)$ is just lower of $Y(i,j)$.

The horizontal axis displays random numbers that are added to the error at quantization. In case of the binary method, random numbers are added to the quantization error. In case of the FS error diffusion method, random numbers are added to the diffusion error. For example, when the random number in the horizontal axis is 10, the adding random numbers are distributed a range from -5 to 5 with a uniform distribution.

From this figure, the likeness of the binary method with the random number that is shown by a blue line decreases largely when the random number increases. That is to say, the white vertical lines are not conspicuous gradually.

Figure 7 shows extension images in the area of P1(0,130) to P2(20,150). Fig. 7(a) is the image of the binary method adding random number 0, Fig. 7(b) is that adding random number 40. Adding 0 means that the random number is not added. From Figs. 7(a) and 7(b) the adding random number decreases a number of the vertical lines. Then we can see the image more naturally.

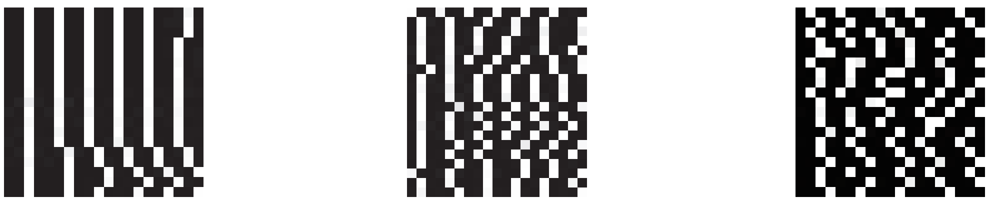
On the other hand, the likeness of the FS error diffusion method with random number, shown by a red line, is almost one tenth as that of the binary method, even if the random number is zero, that is to say in the real FS error diffusion method. Though the white vertical lines remain at the other area for the FS error diffusion method, we change the rectangle pixel area to P1(25,70) and P2(50,95). This area is displayed as the black rectangle shape in the Figure 8. It displays a compressed image using the FS error diffusion method.

Figure 9 shows a relationship between the likeness value and the random number in a rectangle pixel area of P1(25,70) to P2(50,95).

From this figure, the likeness of the FS error diffusion method with the random number, shown by a red line, is smaller than that of the binary method with the random number. Therefore, the white vertical lines for the FS error diffusion method are not more conspicuous than that for the binary method.

Moreover, in both methods the likeness values become the smallest values when the random number is about from 20 to 40.

Figure 10 shows extension images in the area of



(a) Random number 0 (b) Random number 40 (c) Random number 0 for FS error diffusion method.

Fig.7 Extension image for the binary method in the area of P1(0,130) to P2(20,150)

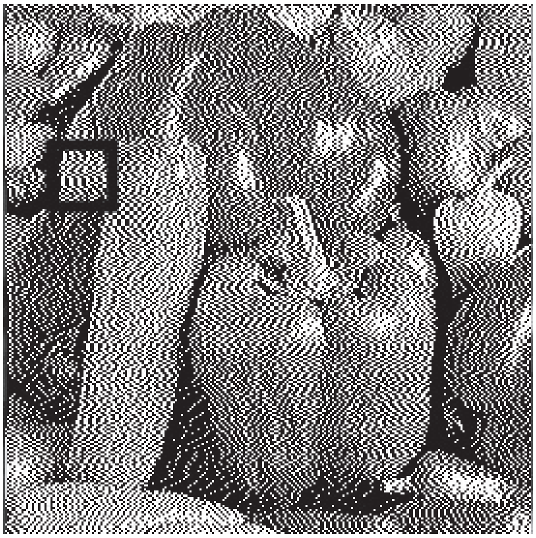


Fig. 8 Compressed image by FS error diffusion method

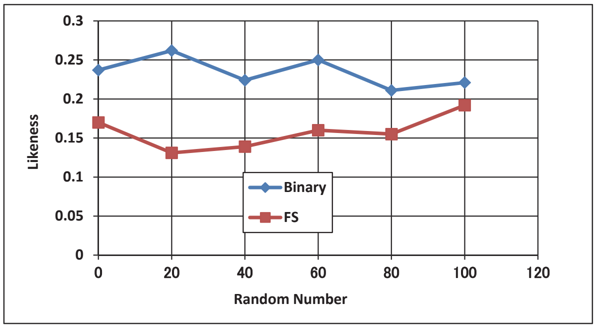


Fig. 9 The relationship between the likeness value and the random number..

(a) Random number 0 (b) Random number 0

Fig. 10 Extension image for the FS error diffusion method in the area of to P1(25,70) and P2(50,95)

P1(25,70) and P2(50,95). Fig. 10(a) is the image of the FS error diffusion method adding random number 0, Fig. 10(b) is that adding random number 40. From Figs. 10(a) and 10(b) we can see that the adding random number in the image becomes paler regular patterns than no adding random number.

3.2 Sharpness SH (10)

Figure 11 shows a relationship between the sharpness values and the random number in all pixels of the image. The vertical axis displays the sharpness of images, - i.e. the preservation degree of the image detail -.

The sharpness SH value is defined as follows,

$$SH=(\Sigma\,\Sigma\,(X_{i,j}-X_{i+1},j)^2)\ /\ ((M-1)*N)\ , \qquad (3)$$

where $X_{i+1,j}$ is the pixel level just right handed side adjacent pixel to $X_{i,j}$. If the SH value for the converted image is a value closer to that for the original image, we can estimate that the converted images are preserved the details including the edge of the image.

From Figure 11 the SHs decrease gradually when the added random numbers become larger in both methods. That is to say, the image blur deteriorates. But below 40 of the random number the SH values are almost flat for both methods, and the image blur is not remarkable.

Figure 12 shows the compressed image adding the random number 40, Fig. 12(a) is by the binary method, Fig. 12(b) is by the FS error diffusion

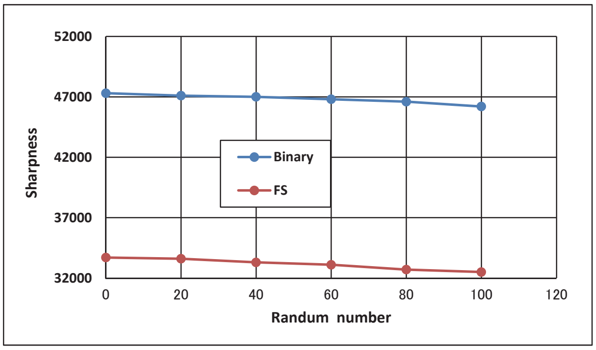
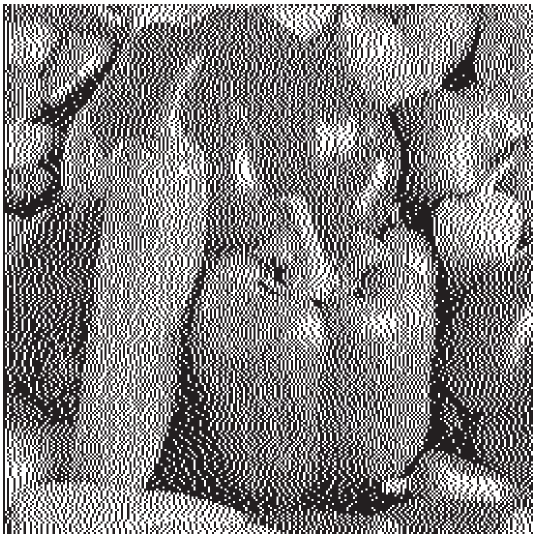
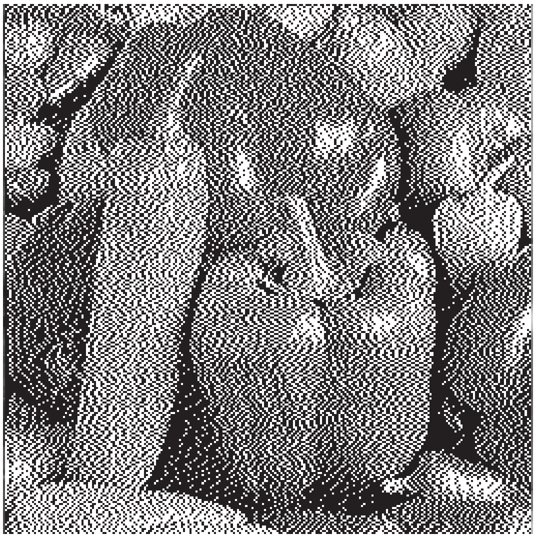


Fig. 11 The relationship between the sharpness value and the random number.



(a) Compressed image by binary method



(b) Compressed image by FS error diffusion method

Fig.12 Compressed image adding random number 40

method. We can see that the image of the FS method decreases conspicuous patterns than the binary method, if the adding random number is 40.

3.3 Comparison of both Methods

The binary method adding the random number is very simple and effective for reducing the conspicuous patterns, keeping the image sharpness. On the other hand, the FS error diffusion method is very effective at the point of decreasing the regular conspicuous pattern such as straight white lines, even if no adding random number. But, the remained conspicuous patterns are removed at some degree by adding random numbers. Moreover, the sharpness keeps almost flat below adding random number 30-40.

4. Conclusion

This paper presents a simple method of image halftoning by adding random number in order to decrease conspicuous patterns such as regular straight lines and patterns. I proposed two simple methods, such as a binary method adding a random number and a FS (Floyd & Steinburg) error diffusion method adding a random number. In the binary method that the converted error is added to only right adjacent pixel, many regular straight lines remained after the converted image, then the images become conspicuous.

By adding a random number, the converted image is natural to look at, but the sharpness of the image does not almost decrease, that is to say, the detail of the image stays unchanged.

In the error diffusion method, where the converted error is transferred 4 adjacent pixels, the regular straight lines decrease than those in the binary method. Moreover, the adding the random number is smaller effective than that for the binary method.

In both methods when the adding random number is about 40, the regular patterns is less. Therefore, the regular patterns are fainter than those for adding random number 0.

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